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Production and marginal analysis of lactating cows subjected to dietary cation-anion balances

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ABSTRACT. The objective of this study was to evaluate productive, nutritional, and economic traits in lactating cows on pasture fed diets with different cation-anion balances (DCAB). Ten lactating ¾ Holstein × ¼ Dairy Gyr cows in the middle third of lactation, at an average age of 70 ± 4.6 months and an average body weight of 400 ± 55.2 kg, were distributed into five treatments in a 5 × 5 Latin square experimental design with two simultaneous squares. Treatments consisted of diets with DCAB of +237, +258, +294, +347, or +419 mEq dry matter (DM). No effects of intake were observed. There was no significant effect of DCAB on milk yield. The milk protein content was not influenced by the DCAB. Body condition score was not significantly affected by the DCAB. The apparent digestibilities of dry matter and nutrients (crude protein, neutral detergent fiber, ether extract, non-fibrous carbohydrates, and total digestible nutrients) were not affected by the DCAB. Marginal rate of return did not show significant differences. Under good conditions of pasture, forage availability, and quality associated with the lactation phases of the cows, all diets were efficient in milk production, dry matter intake, and digestibility. However, in economic terms, the most attractive DCAB was +237 mEq kg^{-1} DM.
Keywords: milk; supplement; cow.

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Introduction

The use of cationic-anionic diets has become an essential tool in dairy farming. Once used solely to prevent metabolic disorders, this technique has shown to provide nutritional and productive improvements, possibly having a great economic impact on the activity.

Recent studies have focused on production and intake in response to the dietary cation-anion balance (DCAB; Harrison et al., 2012; Khelil-Arfa, Faverdin, & Boudon, 2014; Martins et al., 2015), and significant effects are observed on several performance indicators, including dry matter intake, 3.5% fat-corrected milk yield, fat, milk composition, and diet digestibility.

Grazing animals have a high intake of dietary fibrous compounds and may not present responses to DCAB because of their elevated saliva production that results from the high buffer concentration, which in turn allows for a chemical regulation of the rumen environment. Of the many investigations addressing DCAB (Harrison et al., 2012; Khelil-Arfa et al., 2014; Martins et al., 2015), most were conducted in feedlot systems; for this reason, little has been elucidated about their effects on lactating goats on tropical pasture.

The use of cationic-anionic diets may represent significant economic viability with respect to the use of nutrients from the feed, since the climatic inconstancy leads to alterations mainly in the price of grain. Another factor to be taken into consideration is the need for exploiting the tropical pasture more efficiently, given its low cost per kilogram of nutrient. However, scarce information is found in the literature on the effects of DCAB in tropical conditions.

The objective of this study was to evaluate production and undertake a marginal analysis of lactating cows subjected to dietary cation-anion balances.

Material and methods

All experimental procedures were approved by the local Committee of Ethics in Animal Use (case no. 10.918/15). The experiment was conducted in Jequié, state Bahia, Brazil, 13° 51' 27" S and 40° 05' 01" W.

The field work was implemented in a 2-ha area divided into 13 paddocks measuring approximately 0.15 ha each, formed with *Brachiaria brizantha* cv. MG-5. An intermittent system of paddocks with two days of grazing and 24 days of rest was adopted. The area was composed of two rest centers for the animals, with an automatic drinker, a salt trough, and shade available at all times.

A fixed screened-sprinkler irrigation system was adopted with a flow rate of 6 mm hour^{-1}, regulated to maintain ideal moisture using a tensiometer (Soilcontrol®) for the cultivar used. There were distribution variations in the periods between precipitation and irrigation due to the seasonality associated with the winter temperatures that do not allow tropical forages to develop in this time of the year. The experiment lasted 75 days, which were divided into five 15-day periods, consisting of 10 for the adaptation of the animals to the diet with DCAB changes and five days for data collection. Temperature (maximum-minimum thermometer with an amplitude of -40 to +50°C, Walmur®), precipitation (rain gauge with a scale of 0 to 150 mm, Incoterm®), and irrigation data were collected during the experimental period (Table 1).

Table 1. Climatic characteristics and chemical composition of pasture and supplement during the experimental period.

Variable	Period					Mean
	1st	2nd	3rd	4th	5th	
Min. T in shade (°C)	26.6	18.5	21.1	20.9	20.1	21.4
Max. T in shade (°C)	31.3	27.7	31.1	36.3	31.7	31.6
Min. T in the sun (°C)	22.3	18.3	19.2	18.4	17.8	19.2
Max. T in the sun (°C)	35.1	36.4	35.2	37.4	34.0	35.6
Precipitation (mm)	22.5	2.5	14.0	6.5	4.0	9.9
Irrigation (mm)	107	171	33.0	29.0	91.0	86.0
Physicochemical composition of simulated-grazing samples						
DM (g kg^{-1})	238	240	205	289	231	241
CP (g kg^{-1} DM)	96.3	158	177	102	144	135
NDFap (g kg^{-1} DM)	749	742	731	757	742	744
EE (g kg^{-1} DM)	37.2	37.0	43.0	30.7	38.1	37.2
NFC (g kg^{-1} DM)	114	58.7	44.0	108	70.7	78.9
Chemical composition of supplement						
	1st	2nd	3rd	4th	5th	
DM (g kg^{-1} DM)	336	330	322	335	342	333
CP (g kg^{-1} DM)	201	201	201	201	201	201
NDFap (g kg^{-1} DM)	402	402	402	402	402	402
EE (g kg^{-1} DM)	9.70	9.70	9.70	9.70	9.70	9.70
NFC (g kg^{-1} DM)	392	392.7	392.7	392.7	392.7	392.7

1st period: 05/04/2014 to 05/09/2014; 2nd period: 05/28/2014 to 06/02/2014; 3rd period: 06/12/2014 to 06/17/2014; 4th period: 06/27/2014 to 07/01/2014; 5th period: 07/12/2014 to 07/16/2014. Min. T - minimum temperature; Max. T - maximum temperature; DM - dry matter; CP - crude protein; NDFap - neutral detergent fiber corrected for ash protein; EE - ether extract; NFC - non-fibrous carbohydrates.

The pasture was evaluated every two consecutive days during the data collection period, following the methodology described by Braga et al. (2009). Residual daily mass, forage biomass, and daily accumulation rate were determined according to Wilm, Costello, and Klipple (1994), Gardner (1986), and Campbell (1966), respectively.

The potentially digestible dry matter (pdDM) of the pasture was calculated as described by Soares et al. (2019), using the equation below:

$$pdDM = 0.98 \times (100 - \%NDF) + (\%NDF - \%iNDF)$$

where: NDF = neutral detergent fiber; and iNDF = indigestible NDF. The following equations were used to calculate the availability of potentially digestible dry matter (in %) and neutral detergent fiber (pdNDF, %):

$$ApdDM = TADM \times pdDM \text{ and } ApdNDF = TADM \times pdNDF$$

where: ApdDM = availability of pdDM, in kg ha^{-1}; TADM = total available dry matter, in kg ha^{-1}; and ApdNDF = availability of pdNDF, in kg ha^{-1}.

Stocking rate (SR) was calculated considering the animal unit (AU) as 450 kg live weight, using the formula below:

$$SR=(tAU)/Area$$

where: SR = stocking rate, in AU ha^{-1}; tAU = total animal unit; Area = total experimental area, in ha. Forage allowance (FA) was calculated according to the following formula:

$$FA=\{(RBM \times Area + DAR \times Area)/BW_{total}\} \times 100$$

where: FA = forage allowance, in kg DM 100 kg LW^{-1} day^{-1}; RBM = total residual biomass, in kg DM ha^{-1} day^{-1}; DAR = daily accumulation rate, in kg DM ha^{-1} day^{-1}; and BW_{total} = total body weight of the animals, in kg ha^{-1}.

The forage height was measured using a graduated ruler at all forage-collection points. Simulate-grazing (hand-plucked) samples were harvested by following the methodology described by Johnson (1978).

The following values were found in the analysis of the grass samples: dry matter (DM) availability - 5,115 ± 1,192 kg ha^{-1}; green DM availability - 3,053 ± 1,171 kg ha^{-1}; potentially digestible DM - 734.8 ± 8.7 g kg^{-1}; availability of potentially digestible DM - 3,754.55 ± 856.98 kg ha^{-1}; daily residual biomass - 154.49 ± 54.58 kg DM ha^{-1} day^{-1}; stocking rate - 6.06 ± 1.8 AU ha^{-1}; daily accumulation rate - 58.62 ± 9.95 kg DM ha^{-1} day^{-1}; forage allowance - 7.38 ± 1.72 kg DM 100 kg BW^{-1} day^{-1}; forage height - 42.71 ± 11.68 cm; leaf - 22.5%; stem - 37.2%; leaf:stem ratio - 0.62 ± 0.13 g g^{-1}.

Ten lactating ¾ Holstein × ¼ Dairy Gyr cows in the middle third of lactation, at an average age of 70 ± 4.6 months and an average body weight of 400 ± 55.2 kg, were distributed into five treatments in a 5 × 5 Latin square experimental design with two simultaneous squares.

Treatments consisted of diets with DCAB of +237, +258, +294, +347, and +419 mEq DM. The DCAB values in the afore-mentioned treatments were manipulated through levels of sodium bicarbonate in the diet: +237 - 0% inclusion of sodium bicarbonate in the supplement DM; +258 - 0.75% inclusion of sodium bicarbonate in the supplement DM; +294 - 1.50% inclusion of sodium bicarbonate in the supplement DM; +347 - 2.25% inclusion of sodium bicarbonate in the supplement DM; and +419 - 3.00% inclusion of sodium bicarbonate in the supplement DM (Table 1).

The dietary cation-anion balance was calculated as follows: $DCAB= (Na^{+} + K^{+}) - (Cl^{-} + S^{-})$ mEq kg^{-1} of supplement DM. The calculation was obtained based on the percentages of sodium, potassium, chloride, and sulfur in the diet (National Research Council [NRC], 2001) in milliequivalents (mEq), which correspond to the thousandth part of the equivalent, which in turn relates the atomic weight to the cation or anion load.

Cows were supplemented with a concentrate feed containing (per kilogram) 626.8 g ground corn, 235.0 g soybean meal, 94.0 g cottonseed, 25.1 g mineral salt, 3.1 g urea, and 0.3 g ammonium sulfate, formulated to meet the requirements for maintenance and production of 15 L of milk (3.5% fat; NRC, 2001).

The daily handling of the cows began at 5h30, when they were returned from the pasture for the first milking, and the second took place at 16h30. Cows were milked mechanically ('bucket at foot', single file with pit). The supplement was provided immediately after milking (3 kg in the morning and 2 kg in the afternoon) in half-drum troughs with 100 linear centimeters available per animal.

The apparent digestibility and intake of dry matter were estimated from the fecal production, obtained using LIPE® (purified lignin isolated from *Eucaliptus grandis*) as an external marker and indigestible neutral detergent fiber (iNDF) as an internal marker. To estimate fecal production, 500 mg of LIPE® were provided in one daily capsule after the concentrate was offered, over a period of seven days — three for the adaptation and regulation of the marker's excretion flow and four days for feces collection. Feces were harvested once daily upon marker administration, directly from the rectal ampulla, and stored in a cold room at -10°C. To determine the iNDF internal marker, samples of forage, feces, and concentrate were incubated in the rumen of four fistulated animals for 240 hours (Casali et al., 2008), with the residue considered indigestible.

Dry matter intake (DMI) was estimated by the following equation: $DMI = \{[(FO \times CMFe) - MS] / CMFo\} + SDMI$, where: DMI = dry matter intake (kg day^{-1}); FO = fecal output (kg day^{-1}); CMF = concentration of marker in the feces (kg kg^{-1}); MS = presence of marker in the supplement (kg day^{-1}); CMFo concentration of marker present in the forage (kg kg^{-1}); and SDMI = supplement dry matter intake (kg day^{-1}) (Saliba, 2013).

Samples of concentrate, simulated grazing, and feces were pre-dried in a forced-air oven at 55°C for 72 hours. Concentrations of dry matter (DM; Method no. 967.03), total nitrogen (Method no. 981.10), mineral matter (MM; Method no. 942.05) and ether extract (EE; Method no. 942.05) were determined following the Association of Official Analytical Chemists (AOAC, 1997). The neutral detergent fiber content corrected for ash and protein (NDFap) was estimated according to Licitra, Hernandez, and Van Soest (1996). Non-fibrous carbohydrates (NFC) were calculated as proposed by Hall (2000):

$$100 - [\%CP - \%CP \text{ from urea} + \%urea) + \%NDFap + \%EE + \%ash.$$

Milk yield was evaluated from the 11th to the 14th days of each experimental period. 3.5% fat-corrected milk yield ($FCMY^{3.5\%}$) was determined using the following formula (Tyrrell & Reid, 1965):

$FMCY^{3.5\%}$=12.82 x FATp + 7.13 x PRTp + 0.323 x MY

where: $FCMY^{3.5\%}$ = 3.5% fat-corrected milk yield (kg day^{-1}); FAT_P = fat production (kg day^{-1}); and PRT_P = protein production (kg day^{-1}).

The body condition score of the cows was measured by a visual assessment performed by a single trained observer, using a 5-point scale (1 = thin; 5 = fat) in 0.25-unit increments (Edmonson, Lean, Weaver, Farver, & Webster, 1989).

Samples of milk were collected during the morning and afternoon milking sessions proportionally to the production of each period of the day to form a single portion representing the actual daily milk yield. Fat, protein, density, solids-not-fat, and total solids were analyzed by the infrared process in an Ekomilk M® analyzer.

For the marginal analysis, we adopted the partial-budged method, considering the elements that vary with the animals' milk production and with the feeding system of each tested treatment; e.g. pastures, concentrate (corn, soybean meal, cottonseed), and mineral salt. The costs of concentrate in Bahia State were obtained considering the intake and price of ingredients collected during the experiment.

Subsequently, we evaluated the revenues from the sale of milk per treatment by using the price of milk corresponding to the average price paid in the state of Bahia (Brazil), as surveyed by the Center of Advanced Studies in Applied Economics at ESALQ/USP. The evaluation was based on the following variables: gross revenue from the sale of milk (GRSM) and revenue minus feed costs (RMFC - difference between the gross revenue from the sale of milk and the total feed cost). The marginal rate of return (MRR) was calculated according to the methodology proposed by Evans (2005), using the following formula:

$$MRR = (RMFC_{standard} - TFC_{standard} / TFC_{test} - TFC_{standard}) \times 100.$$

Results were analyzed statistically by variance and regression analyses at the 0.95 probability level using the SAEG (*Sistema de Análises Estatísticas e Genéticas*) software version 9.0. (Ribeiro Júnior, 2007).

Results and discussion

There was no effect (p > 0.05) of the dietary cation:anion balances (DCAB) on nutrient intake or milk yield and composition of lactating cows on tropical pasture (Table 2).

The change in the intakes of total DM and forage DM are related to the limiting physical factor originating from the fiber from the pasture, which implies a greater rumen fill, increasing the residence time of NDF in the rumen. By contrast, the literature describes that a cationic diet would elevate the amount of fiber-degrading microorganisms, resulting in higher rates of emptying and a consequent increase in intake, which was not observed in the current study.

Table 2. Production and feed intake of lactating cows on tropical pasture subjected to dietary cation-anion balances (DCAB).

Item	DCAB					EPM	p linear	p quad	RE
	+237	+258	+294	+347	+419				
	Intake (kg day^{-1})								
TDM[1]	11.5	11.6	11.4	12.2	11.5	1.874	0.40611	0.38752	Ŷ = 11.7
FDM[2]	7.20	7.20	7.00	7.70	7.00	1.874	0.32870	0.14322	Ŷ = 7.20
CP[3]	1.92	1.92	1.95	1.91	1.94	0.444	0.43480	0.15640	Ŷ = 1.93
NDF[4]	6.14	6.14	6.10	6.18	6.10	1.364	0.30558	0.83270	Ŷ = 6.13
EE[5]	0.27	0.27	0.27	0.27	0.27	0.086	0.64290	0.86422	Ŷ = 0.27
NFC[6]	1.66	1.65	1.66	1.61	1.67	0.168	0.42932	0.24386	Ŷ = 1.65
TDN[7]	6.65	6.54	6.74	6.88	6.64	1.840	0.28549	0.14382	Ŷ = 6.69
	Milk yield and composition								
MY[1]	11.7	10.2	10.6	10.8	9.9	0.131	0.53433	0.75493	Ŷ = 10.6
$^{3.5\%}$FCMY[1]	13.4	12.5	12.3	12.9	11.8	2.993	0.18983	0.12983	Ŷ = 12.6
Fat[2]	45.2	50.6	46.2	48.1	47.1	7.171	0.32843	0.28754	Ŷ = 47.4
Protein[2]	35.3	35.7	35.4	35.5	35.9	0.772	0.63233	0,73344	Ŷ = 36.0
SNF[2]	93.4	94.4	93.8	93.9	94.9	10.130	0.84434	0.64998	Ŷ = 94.1
TS[2]	140	145	140	142	142	8.242	0.56733	0.58992	Ŷ = 141.5
BCSC[3]	0.40	-0.10	0.10	-0.30	0.60	0.074	0.66443	0.88654	Ŷ = 1.4

CV - coefficient of variation; RE - regression equation. Quad – Quadratic; TDM - total dry matter; FDM - forage dry matter; CP - crude protein; NDFap - neutral detergent fiber; EE - ether extract; NFC - non-fibrous carbohydrates; TDN - total digestible nutrients; MY - milk yield; $^{3.5\%}$FCMY - 3.5% fat-corrected milk yield; SNF - solids-not-fat; TS - total solids; BCSC - body condition score change. [1]kg d^{-1}, [2]g kg^{-1}, [3]Points.

Crude protein intake did not vary ($p > 0.05$), because the animals received concentrate supplement and forage with the same composition and in the same quantity. Van Amburgh et al. (2015) reported that the digestion rate of fraction A of the true protein is 130-300% per hour. However, literature values are typically lower (NRC, 2001; Hedqvist & Udén, 2006; Lanzas, Tedeschi, Seo, & Fox, 2007) and indicate that the degradation rate of protein fraction A is slower than what was initially considered in CNCPS and rapidly soluble, and thus no time has been estimated for its degradation (Sniffen, O'Connor, Van Soest, Fox, & Russell, 1992).

No effects of NDF intake were observed with the increasing DCAB ($p > 0.05$). The average NDF intake was 6.13 kg day^{-1} or 1.53% body weight, which is within the Brazilian average and close to the 6.7 kg day^{-1} found by Mendes et al. (2013) in lactating crossbred cows receiving diets with concentrate levels.

Ether extract intake was not significantly affected by the DCAB ($p > 0.05$), because the largest source of EE in the total diet of the cows originated from the pasture (37.3 g EE kg^{-1} DM); however, intake is restricted because NDF is present in the forage, making it a limiting factor for EE intake. This effect can be explained by the lack of significant effects on NDF intake.

In the present study, the diet had a NFC content of approximately 141 g kg^{-1} DM, and the NRC (2001) recommends that the maximum limit for NFC be established as a function of the fibrous fraction of the diet (NDF and ADF), which is around 200 to 230 g kg^{-1} DM. Therefore, based on these values, there would be significant responses to an increase in DCAB.

Total digestible nutrients intake was not affected by the DCAB ($p > 0.05$). The NRC (2001) recommends of 335 g TDN kg^{-1} DM for every 90 g CP kg^{-1} DM, both per kilogram of milk produced. The present work revealed very close values: 335 g TDN kg^{-1} DM for every 94 g CP kg^{-1} DM. Therefore, an increase in this nutrient would not be interesting for milk production because of the loss of energy that would stem from the energy:protein imbalance.

There was no significant effect of DCAB on milk yield ($p > 0.05$). The lack of an effect of DCAB on milk yield may be related to a high intake of fibrous content originating from the pasture, which stimulated chewing, producing saliva, which contains a high concentration of sodium bicarbonate that buffers the rumen. It would be possible to elevate milk production per area maintaining the same intake of dry matter by increasing the level of concentrate in the diet and the number of animals per area, since there would be a larger amount of available pasture. Iwaniuk and Erdman (2015) also did not observe variations in milk yield with an increase in DCAB. This occurred because of the lack of changes in DM intake, given that it is possible that an increase in milk yield is a consequence of a higher intake, which would lead to more energy and nutrients available for production.

No significant differences were observed in 3.5% fat-corrected milk yield ($^{3.5\%}$FCMY) as a function of the DCAB levels ($p > 0.05$). Hu, Murphy, Constable, and Block (2007) associated a variation in $^{3.5\%}$FCMY to fat (kg day^{-1}) and protein (kg day^{-1}) production, because it is part of the equation that corrects the actual milk yield value, including fat, which is one of the factors determining the variation in $^{3.5\%}$FCMY. Iwaniuk and Erdman (2015) observed significant effects, with an increase in $^{3.5\%}$FCMY from 25.5 to 28.9 kg day^{-1} when DCAB was increased from 0 to 500 mEq kg^{-1} DM, with incremental responses of 1.02, 0.92, 0.82, 0.74, and 0.67 kg d^{-1} for every addition of 100 mEq kg^{-1} in DCAB. Therefore, the lack of effects in the present study may be associated with a lower production level.

There were no significant effects on the fat content as a function of the DCAB ($p > 0.05$), which may be related to the lack of changes in fermentation pattern resulting from the supplied diets, directly affecting the substrate generated for the synthesis of fat in the mammary gland. According to Marques et al. (2011) and Barbosa et al. (2012), the milk components can be changed directly by the nutritional and metabolic status of dairy cows; however, the present results do not corroborate Khelil-Arfa et al. (2014), Iwaniuk and Erdman (2015), or Martins et al. (2015), who pointed DCAB as an influencer of changes in milk composition, especially fat, which is closely related to the degradation of the fiber due to the greater growth of cellulolytic bacteria.

Results different from ours were obtained by Iwaniuk and Erdman (2015), who reported that fat production in milk rose from 0.89 to 1.07 g when DCAB was increased from 0 to 500 mEq kg^{-1} DM, which resulted in a 36.0 g increase for every 100 mEq kg^{-1} increase in DCAB. However, the conditions of the experimental units in terms of milk production were different from the current study, since high/medium-producing (26 kg day^{-1}) and low-producing (10 kg day^{-1}) animals were used, respectively.

This suggests that the amount of concentrate feed offered would be larger for medium/high-producing cows, causing the DCAB to exert is function more expressively. By contrast, it can be affirmed that the pasture may perform functions that would prevent a decline in fat content based on the amount of roughage consumed through the roughage:concentrate ratio of 62:38; this roughage originates from the *Brachiaria brizantha* cv MG-5 pasture.

The milk protein content was not influenced by the DCAB ($p > 0.05$), and the bacteria responsible for glucose utilization were likely not affected, because a positive DCAB prevents the release of H^+ ions, which led to a reduction in energy loss by means of a heat increment; i.e. via methane (CH_4). This maintained the rumen temperature constant and consequently the passage of amino acids into the rumen was not affected. There was no effect of DCAB on solids-not-fat or total solids, since there was no variation in the main constituents that compose them.

Body condition score change was not significantly affected by the DCAB ($p > 0.05$) because of the lack of an increase in DM intake and consequently in nutrient availability. This finding can also be attributed to the fact that milk yield remained constant as the DCAB levels were elevated and no increase occurred in the amounts of energy and protein for the formation of adipose tissue.

Body condition score is associated with the maximum genetic capacity for milk production of lactating cows. When it is reached, the animal body starts to deposit energy reserves in the form of tissue. The NRC (2001) reports that BCS is related to fat, protein, and energy contents in the body, responsible for 65, 52, and 66% of their variations, respectively.

The apparent digestibilities of dry matter and nutrients (CP, NDF, EE, NFC, and TDN) were not affected by the DCAB ($p > 0.05$; Table 3). A high digestibility does not always imply a higher rate of passage, but determines the efficiency of activity of microorganisms and enzymes, preventing nutrients from being excreted in the feces. Amanlou, Farahani, and Farsuni (2017) evaluated nutrient digestibility in lactating cows using a diet with a similar protein content to that of the present study (160 g kg^{-1} DM) and found the same result for DM digestibility obtained in this experiment (64.4%). However, lower values were obtained by that author for CP and NDF (69.2 and 49.4%, respectively), indicating that even if the DCAB did not show significant differences from each other, the minimum value of +237 mEq kg^{-1} DM was sufficient to elicit improvements in the digestibility of these nutrients.

The DCAB provided via supplement likely did not influence the rumen pH in a very expressive manner, because it was fractionated into the morning and afternoon periods, allowing a limitation of concentrate consumption in a short time and thus preventing elevated peaks of volatile fatty acid concentrations and maintaining ruminal stability.

Table 3. Apparent digestibility and marginal analysis of the production of lactating cows on tropical pasture subjected to dietary cation-anion balances (DCAB).

Item	DCAB					EPM	p linear	p quad	RE
	+237	+258	+294	+347	+419				
	Apparent digestibility (%)								
DM	64.1	63.4	64.9	66.3	64.6	6.971	0.40611	0.20310	Ŷ = 64.6
CP	75.0	72.6	74.1	75.3	73.6	6.566	0.32863	0.11324	Ŷ = 74.1
NDF	57.6	57.2	58.8	60.7	58.2	9.808	0.30558	0.18732	Ŷ = 58.5
EE	25.3	17.3	22.5	30.0	23.5	9.748	0.10090	0.54283	Ŷ = 23.8
NFC	84.5	84.5	85.8	85.0	85.6	3.364	0.09683	0.11321	Ŷ = 85.1
TDN	65.5	64.4	66.2	67.8	65.7	6.451	0.23404	0.14387	Ŷ = 65.9
	Costs								
TRC[1]	3.23	3.10	3.22	3.48	3.17	0.297	0.42392	0.37231	Ŷ = 3.24
CC[1]	4.20	4.58	5.02	5.41	5.85	0.432	0.13212	0.84732	Ŷ = 5.01
TFC[1]	7.43	7.68	8.24	8.89	9.02	1.423	0.53420	0.78944	Ŷ = 8.25
	Economic indicator								
GRSM[1]	12.86	12.98	12.33	12.92	12.54	2.892	0.64530	0.78594	Ŷ = 12.73
RMFC[1]	5.43	3.79	4.09	4.04	2.09	0.391	0.84393	0.76549	Ŷ = 3.89
MRR[2]	0	-161.06	-188.97	-143.74	-175.85	8.564	0.67432	0.68322	Ŷ = -167.40

CV - coefficient of variation; RE - regression equation. Quad – Quadratic; DM - dry matter; CP - crude protein; NDFap - neutral detergent fiber; EE - ether extract; NFC - non-fibrous carbohydrates; TDN - total digestible nutrients; TRC - total roughage cost; CC - concentrate cost; TFC - total feed cost; GRSM - gross revenue from the sale of milk; RMFC - revenue minus feed costs; MRR - marginal rate of return. [1]BRL day^{-1}, [2]%.

However, meta-analysis studies led by Iwaniuk and Erdman (2015) in which they evaluated digestibility in a DCAB range (13 to 436 mEq kg^{-1}) revealed that an increase in DCAB resulted in higher DM digestibility (67.5 to 70.5%), with a 0.73% augment with every 100 mEq kg^{-1} increase in DCAB. The works published by those authors indicate that animals subjected to DCAB received concentrate supplement *ad libitum*, but the data did not inform the DM intake values.

Total costs of roughage, concentrate, and feed averaged BRL 3.24, 5.01, and 8.45, respectively. These variables were not significantly affected ($p > 0.05$), as they were directly related to daily intake, since the ingredient costs were fixed except for the manipulation of DCAB via sodium bicarbonate, which showed a numerical variation of BRL 0.17 for every 100 mEq kg^{-1} increase in DCAB. The cost of concentrate per treatment per day was BRL 4.20, 4.58, 5.02, 5.41, and 5.85, for treatments +237, +258, +294, +347, and +419 mEq, respectively. In terms of scale, we can observe the great impact of sodium bicarbonate on the dairy-cattle feeding system, as these values were calculated on the basis of the price adopted in the northeast region of Brazil: BRL 2.20 per kilogram.

No significant effect was detected ($p > 0.05$) for GRSM, which averaged BRL 12.69 with a fixed paid price of BRL 1.10 per liter of milk. There were no significant effects for gross margin (RMFC), which averaged BRL 3.88 per day. In both cases, the lack of significant effects was due to the inexistence of alterations in milk yield, which was the main cause of the variations in revenue. However, in high-producing cows with a high intake of dietary concentrate, different results may be seen as the stocking rate is increased.

The marginal rate of return did not show significant differences ($p > 0.05$). This variable represents the difference obtained with an increment in return as a percentage of the total additional cost (Evans, 2005). Although no significant effects were present between the treatments, they showed negative values, representing losses to the system. In this regard, treatment +237 (no sodium bicarbonate) stood out as the most attractive.

According to Vasconcellos and Oliveira (2000), production efficiency should not only be considered in technical terms; it should also be made efficient in the economic aspects; i.e. its activities must be undertaken at minimum cost. Both the technical and economic concepts consider the production cost as the expenditure required for the generation of product, but the economic concept considers price as the so-called 'opportunity cost' of these factors.

The milk-feed price ratio was found to be BRL 1.66 for every BRL 1.00 invested, which is considered a low value, since no other costs such as vaccination, labor, or depreciation were taken into account that might also reduce the milk-feed price ratio. A factor that might contribute positively in this scenario would be an increase in stocking rate and readjusting the diet for a daily milk production of 10 kg, because the diet used in the present study was formulated for the production of 15 kg of milk per day, aiming to promote a substitution effect of the forage and stimulate maximum milk production by the cows.

This study presented an average milk yield of 106 kg day^{-1}, and Arêdes, Silveira, Lima, Arêdes, and Pires (2006) found that the average total cost of farms with production larger than 300 L day^{-1} is 1% lower than that of holdings with production lower than the above-mentioned value. This suggests that analyzing the cost and determining the existence of economy of scale in the dairy activity is a decisive factor for competitiveness inasmuch as an increase in production volume would imply decreasing production costs.

Conclusion

The production of lactating cows receiving up to 38% concentrate supplementation in diets with tropical forage as the fiber source is not changed by the dietary cation-anion balance. Therefore, under good conditions of pasture, availability, and quality, coupled with the lactation stages of the cows, all diets are efficient in milk production, dry matter intake, digestibility, and also in economic and management terms. The most attractive dietary cation-anion balance is +237 mEq kg^{-1} dry matter, which can be obtained without the inclusion of sodium bicarbonate as one of the concentrate ingredients.

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